Research Report

Cardiovascular Responses to Repetitive McKenzie Lumbar Spine Exercises

Background and Purpose. Repetitive exercises of the type recommended by McKenzie for the lumbar spine, such as flexion and extension exercises in standing (FIS and EIS) and lying positions (FIL and EIL), have been used in the management of low back pain for over 20 years. The cardiovascular effects of exercises that involve postural stabilization and the arms and of exercises performed in a lying position are well known. Therefore, the purpose of this study was to examine the cardiovascular effects of 4 exercises used in the McKenzie system. **Subjects and Methods.** One hundred subjects without cardiovascular or cardiopulmonary disease (mean age=31 years, SD=6.1, range=22–44) and who were representative of people susceptible to low back pain were studied. Subjects were randomly assigned to 1 of 4 exercise groups (ie, FIS, EIS, FIL, and EIL). Subjects performed sets of 10, 15, and 20 repetitions of the assigned exercise, with a 15-minute rest between sets. Heart rate, blood pressure, and rate-pressure product (an index of myocardial work) were recorded before and after each set of repetitions. **Results.** After 10 repetitions, flexion and extension in lying were more hemodynamically demanding than in standing. This trend persisted for 15 and 20 repetitions; however, at 20 repetitions, the hemodynamic demands were different across exercise groups (ie, FIL>EIL>FIS>EIS). **Discussion and Conclusion.** Repetitive exercises of the type suggested by McKenzie for the lumbar spine can have cardiovascular effects in people with no cardiovascular or cardiopulmonary conditions. These effects may be important with respect to cardiac work, and patients for whom these exercises are indicated should have a cardiac and pulmonary risk factor assessment to determine whether heart rate and blood pressure should be monitored. [Al-Obaidi S, Anthony J, Dean E, Al-Shuwai N. Cardiovascular responses to repetitive McKenzie lumbar spine exercises. *Phys Ther*. 2001;81:1524–1533.]

Key Words: *Blood pressure, Cardiovascular responses, Extension in lying, Extension in standing, Flexion in lying, Flexion in standing, Heart rate, Low back pain, McKenzie lumbar spine exercises, Rate-pressure product, Repetitions.*

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For 2 decades, lumbar spine exercises advocated by McKenzie for low back pain have been used for the management of patients with spinal disorders.[1–4] These exercises are used to classify patients as having 1 of 3 syndromes (postural, dysfunction, and derangement syndromes) and to guide treatment.[4] These exercises include repeated flexion and extension movements performed in different body positions as part of a routine lumbar spinal assessment and exercise program.[4,5] Although 10 to 15 repetitions are recommended by McKenzie,[6] the cardiovascular effects of this number of repetitions have not been studied. Because of this omission, we believe clinicians might assume that these exercises constitute a safe submaximal load with no consequential cardiovascular effects, even when repeated several times a day as recommended for a home program.[4]

The initial McKenzie spinal assessment involves sets of 10 to 15 repetitions of spinal loading exercises performed in different positions.[1,3,4] To obtain favorable responses, or "centralization of symptoms," to McKenzie exercises, a clinician may instruct the patient to do more than 10 to 15 repetitions of a specific McKenzie exercise. Some patients with acute or chronic low back pain will show a favorable response; however, other patients may require more repetitions. For example, to document the immediate responses of symptoms to the performance of the McKenzie exercises, Donelson and colleagues[7] reported using 4 sets of 10 repetitions of lumbar flexion and extension with 30 to 60 seconds between sets. With the introduction of the end-range passive exercise table, a clinician is able to apply repeated cycles of progressive lumbar end-range exercise in the lying position.[6] Based on the McKenzie approach, a patient performing 10 or 15 repetitions every 2 hours in a home program implies that end-range exercise will be attained 80 to 100 times a day. Although 10 to 15 repetitions are recommended for a home program based on the McKenzie approach, some patients, believing "more is better," may perform more than the prescribed number of repetitions. The

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number of repetitions and the type of exercise can affect the overall physiologic demand of exercise.[8]

Some risk factors for back pain are similar to those associated with cardiovascular disease (eg, lack of physical conditioning, obesity, smoking).[9–13] Several authors[11,14–17] have reported a high incidence of chest pain on exertion, breathlessness, coughing, and high blood pressure (BP) in patients with back pain. This evidence suggests that clinicians working with patients who have low back pain need to consider that there can be an increased risk of an adverse cardiovascular response.

The McKenzie exercises involve muscle co-contraction to stabilize the trunk and arm exercise, both of which are associated with disproportionate cardiovascular demand to a given load compared with leg work.[18–20] Patients with cardiac conditions or high BP are routinely cautioned about exercises requiring isometric muscle contractions and arm work,[21–23] because these exercises are associated with increased cardiovascular stress as manifested by increased work of the heart, which is reflected by increased heart rate (HR) and BP for a given submaximal load compared with leg exercise. The cardiovascular effects of repetitive McKenzie exercises could have implications for patients with low back pain who have coexistent cardiovascular conditions. Guidelines for the use of these exercises, however, are typically not accompanied by cautions about potential cardiovascular stress. Thus, understanding the cardiovascular responses to McKenzie exercises can be useful for clinicians using these exercises for diagnostic purposes and as an intervention.

Direct measurement of myocardial work as a function of myocardial oxygen demand involves invasive techniques and is not feasible for routine clinical examination. Simple noninvasive measures of cardiovascular responses, however, can be obtained with HR, systolic BP, and the rate-pressure product (RPP).[24–27] The RPP is the product of HR and systolic BP multiplied by 10^{-2}. The RPP is considered an excellent index of myocardial oxygen demand and, therefore, work of the heart.[25,26]

Several researchers[21,25,26,28–30] have investigated the effect of various types of submaximal work performed by the upper extremities on the RPP versus the lower extremities. The increase in HR and systolic BP per unit of increase in work is greater during upper-extremity exercise than during lower-extremity exercise.[25,31–35] Isometric exercise has been shown to increase both HR and BP and, therefore, RPP.[8,33] Increases in HR and BP are proportional to the torque produced by the muscles.[36,37] Lumbar spinal flexion and extension involve upper-extremity work using both concentric and eccentric contractions. Eccentric muscle contractions are associated with less oxygen demand (and, therefore, less cardiovascular stress) than exercises with concentric muscle contractions.[38] These distinctions could become important when patients with low back pain and with symptomatic or asymptomatic cardiovascular disease perform McKenzie-type exercises.

To our knowledge, there are no studies of the cardiovascular effects of repetitive McKenzie exercises. The aim of our study, therefore, was to examine the cardiovascular effects of 4 common McKenzie exercises—lumbar spinal flexion and extension in standing and lying—when these exercises are repeated 10, 15, and 20 times. We hypothesized that repetitive McKenzie exercises of the lumbar spine would produce marked changes in the work of the heart and that these effects increase with multiple repetitions.

Method

Subjects

One hundred subjects (59 men, 41 women) volunteered to participate in this study. The male subjects had a mean age of 31 years (SD=6.1, range=22–43), and the female subjects had a mean age of 30.6 years (SD=6.7, range=22–44). According to McKenzie, this age range represents individuals at risk for pathology of the spine, specifically postural syndrome (30 years of age and younger), dysfunction syndrome (30 years and older), and derangement syndrome (20–55 years).[4,6] The sample was one of convenience and included university students and staff. Based on a questionnaire and interview, subjects were excluded from the study if they reported a history of cardiovascular or pulmonary conditions, anemia, recent musculoskeletal injury, history of low back pain, intervertebral or facet joint pathology, or a history of metabolic disorders or smoking. We chose to eliminate individuals with these pathologies so that we could first establish the cardiovascular effects of McKenzie exercises in the absence of pathology in this preliminary study. Before testing, subjects were informed about the purpose of the study, the risks, and their right to terminate participation at any time. All subjects acknowledged their understanding of the study and their willingness to participate by providing signed consent.

Testers

The 2 physical therapists who conducted the testing had completed the basic 4-part (A to D) series of McKenzie courses and had an average of 7 years of experience working with the McKenzie system.

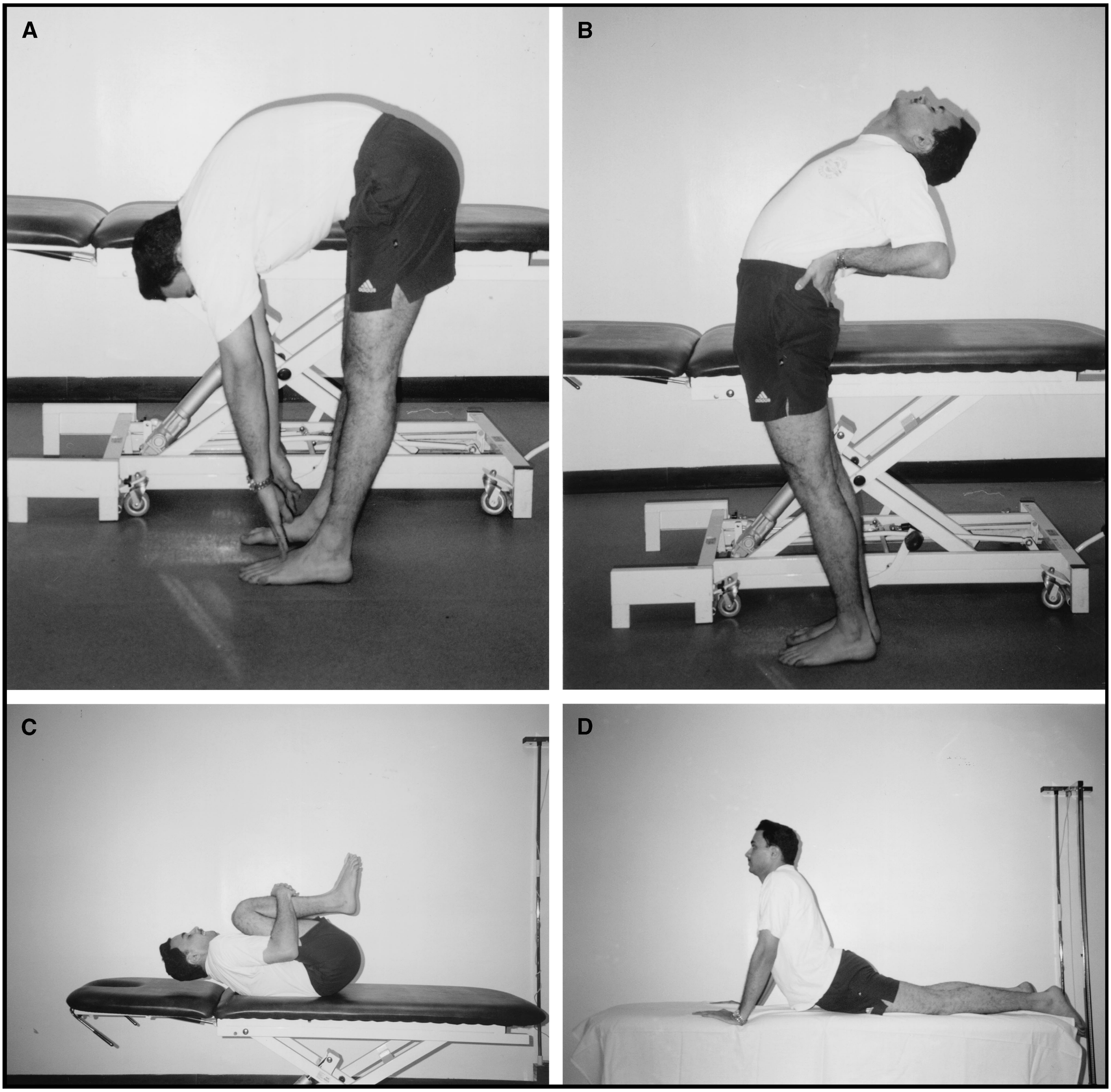

Figure 1.
Repetitive McKenzie spinal loading exercises (lumbar flexion and extension) performed in standing and lying: (A) flexion in standing (FIS), (B) extension in standing (EIS), (C) flexion in lying (FIL), (D) extension in lying (EIL).

Research Design

To examine the cardiovascular effects of the 4 exercise groups, we randomly assigned subjects in blocks so that each group consisted of 25 subjects. The exercise groups were designated as flexion in standing (FIS), extension in standing (EIS), flexion in lying (FIL), and extension in lying (EIL) (Fig. 1). The experimental protocol was based on established clinical standards for performing repetitive exercises of the lumbar spine as advocated by McKenzie.[4] These exercises are performed in an almost continuous rhythm. On each movement, the subject reaches the maximum possible end range of his or her lumbar spine in the direction of the movement and maintains the position for 1 to 2 seconds before the next repetition. For the purposes of our study, subjects were instructed not to hold their breath. A patient normally completes 10 to 15 repetitions within 1 minute.[1–4] Subjects became familiar with 1 of the 4 exercises by verbal instruction, demonstration, and practice, before being instructed to perform the exercise for 3 sets of consecutive repetitions (10, 15, and 20 repetitions). They rested 15 minutes after each set to ensure that their HR and BP returned to resting levels prior to performing the next set of repetitions.

Table 1.
Statistics for Intratester and Intertester Reliability[a]

Intratester Reliability	$\bar{X}$	SD	*r*	ICC	95% CI	SEM
Heart rate						
Tester 1			.90[b]	.94	.89–.94	.85
Trial 1	80.8	2.81				
Trial 2	80.6	2.56				
Tester 2			.96[b]	.98	.94–.99	.54
Trial 1	80.8	2.76				
Trial 2	81.0	2.88				
Systolic blood pressure						
Tester 1			.94[b]	.96	.89–.98	2.5
Trial 1	107.5	9.92				
Trial 2	104.8	11.55				
Tester 2			.99[b]	.99	.994–.999	.64
Trial 1	106.1	10.18				
Trial 2	105.6	10.61				
Diastolic blood pressure						
Tester 1			.97[b]	.98	.96–.99	.73
Trial 1	77.9	4.62				
Trial 2	76.8	4.88				
Tester 2			.97[b]	.98	.95–.99	.83
Trial 1	77.3	4.99				
Trial 2	77.2	5.00				

Intertester Reliability	ICC	95% CI
Heart rate	.93	.85–.97
Systolic blood pressure	.97	.95–.98
Diastolic blood pressure	.97	.93–.99

[a] *r*=Pearson product moment correlation, ICC=intraclass correlation coefficient, CI=confidence interval, SEM=standard error of the measurement.
[b] $P<.01$.

Data Collection

Prior to testing, the height and weight of each subject were recorded. The subject was then seated in a relaxed position in a firm armchair for 5 minutes, during which time a questionnaire was completed and the consent form was reviewed and signed. The questionnaire elicited information about the subject's exercise history and activity levels. To establish whether the sample was homogeneous concerning activity and fitness level, activity was rated on a 3-point scale (ie, I=regular sports participant, II=irregular sports participant, and III=not a sports participant).

The reference position, in which HR and BP were recorded, was sitting in a chair. Arterial BP was obtained with a sphygmomanometer applied to the left arm. Cuff width, position, tightness, and deflation rate were controlled in accordance with American Heart Association standards to maximize the validity (ie, agreement with intra-arterial measurements, reliability of the measurements).[39] Using a digital stopwatch, the tester determined the resting HR of the seated subject by counting the left radial arterial pulse for 30 seconds and multiplying the value by 2 to obtain a minute rate. The subject then performed 10 repetitions of the assigned exercise and, on completion, was instructed to assume the initial resting position.

After each set was completed and the subject returned to the reference position (within 30 seconds), the tester recorded HR and BP. The mean of 2 measurements of HR and BP were obtained from each subject after each set. The RPP was calculated by multiplying mean HR and mean arterial systolic BP and then multiplying the product by 10^{-2}. The same protocol was repeated after the sets of 15 and 20 repetitions of the assigned exercise. During the 15-minute rest period between exercise sets, cardiovascular measurements were recorded until they returned to baseline. The HR and BP data were used to calculate the RPP after each set of repetitions.

Because 2 testers were involved in data collection, intratester and intertester reliability for obtaining HR and BP were determined prior to the study, using the same equipment and standardized procedures,[27,39] for 15 subjects. The statistics for intratester and intertester reliability of the 3 primary measures (ie, HR, systolic BP, and diastolic BP)—including intraclass correlation coefficients (ICCs) calculated from the analyses of variance for the intratester data and for the intertester data, standard

Table 2.
Demographic Information[a]

	Group				
	FIS (n=25)	EIS (n=25)	FIL (n=25)	EIL (n=25)	Total
Sex					
Male	13	14	15	14	56
Female	12	11	10	11	44
Age (y)					
$\overline{X}$	31.0	30.8	31.7	29.8	30.8
SD	6.91	6.6	6.56	3.95	6.07
Range	22–44	23–44	23–42	22–37	22–44
Height (cm)					
$\overline{X}$	169.3	170.6	170.1	171.9	170.5
SD	8.18	6.26	9.07	5.82	7.40
Range	154–180	158–183	153–180	160–183	153–183
Weight (kg)					
$\overline{X}$	75.6	73.5	75.3	73.0	74.5
SD	6.77	9.81	7.39	8.54	8.16
Range	60–84	57–92	63–87	57–86	57–92
BMI (kg/m^2)					
$\overline{X}$	26.1	24.7	25.8	24.4	25.3
SD	2.72	3.84	1.96	2.43	2.87
Range	21.7–33.2	20.3–36.8	21.0–29.8	18.9–27.2	18.9–36.8
Activity level					
I	8	7	6	4	25
II	5	5	4	6	20
III	12	13	15	15	55

[a] FIS=flexion in standing, EIS=extension in standing, FIL=flexion in lying, EIL=extension in lying, BMI=body mass index, activity level I=regular sports participant, II=irregular sports participant, III=not a sports participant.

errors of the measurement, and the 95% confidence intervals—are displayed in Table 1. The measurements were shown to be highly reliable,[40] with all ICCs equal to or greater than .93. For tester 1, the mean systolic BPs for trials 1 and 2 were 107.5 mm Hg and 104.8 mm Hg, respectively, with an ICC of .96. For tester 2, the mean systolic BPs for trials 1 and 2 were 106.1 mm Hg and 105.6 mm Hg, respectively, with an ICC of .99.

Data Analysis

Descriptive statistics for the dependent measures, including means and standard deviations, were calculated for each set for the 4 exercise groups. A one-way analysis of variance (ANOVA) for repeated measures was used to compare the dependent measurements obtained at rest and after performing the assigned exercises for 10, 15, and 20 repetitions. Scheffe multiple-comparison *post hoc* analysis was used to determine which group or groups were significantly different from the others. The level of significance was set at .05.

Results

The demographic information for the subjects is presented in Table 2. The subjects had a mean age of 30.8 years (SD=6.07, range=22–44), a mean height of 170.5 cm (SD=7.40, range=153–183), a mean weight of 74.5 kg (SD=8.16, range=57–92), and a mean body mass index of 25.3 kg/m^2 (SD=2.87, range=18.9–36.8). Table 2 also shows the subject activity level. The majority of subjects reported an activity level of III (ie, they were not a sports participant). Table 3 shows the resting HRs, systolic and diastolic BPs, and the RPP for the 4 exercise groups after 10, 15, and 20 repetitions of each type of exercise. No differences were observed among the groups with respect to both demographic data and resting cardiovascular measurements, indicating that the groups were homogenous.

The HR, BP, and RPP increased proportionately with increasing repetitions. Because the results for HR and BP were comparable, only the results for RPP are shown graphically (Fig. 2). Increases in RPP were observed for 15 and 20 repetitions in 3 of the groups (Tab. 3)—FIS, FIL, and EIL—whereas the EIS group showed no difference from baseline. After 15 and 20 repetitions, however, differences were accentuated with increasing number of repetitions, and these differences were accentuated further when subjects were lying compared with standing.

Table 4 presents a summary of the ANOVA results for RPP among groups and repetitions. Because HR and BP changes corresponded to those for RPP and because RPP is the product of these 2 variables, only the ANOVA

Table 3.
Cardiovascular Measurements for the Four Exercise Groups at Baseline and After 10, 15, and 20 Repetitions[a]

Heart Rate (bpm)

Exercise Groups	Baseline			10 Repetitions			15 Repetitions			20 Repetitions		
	$\bar{X}$	SD	Range	$\bar{X}$	SD	Range	$\bar{X}$	SD	Range	$\bar{X}$	SD	Range
FIS	78.8	3.04	74–84	87.1	6.79	74–96	89.4	8.67	78–112	90.9	7.89	80–120
EIS	81.9	3.39	74–90	81.4	8.60	70–105	78.8	13.20	62–102	78.9	12.91	64–106
FIL	81.5	5.69	74–102	88.7	12.44	68–114	102.6	10.24	85–120	145.1	9.31	126–164
EIL	79.8	4.00	72–84	91.3	9.35	80–105	98.2	10.05	84–120	112.3	9.33	95–134

Systolic BP (mm Hg)

Exercise Groups	Baseline			10 Repetitions			15 Repetitions			20 Repetitions		
	$\bar{X}$	SD	Range	$\bar{X}$	SD	Range	$\bar{X}$	SD	Range	$\bar{X}$	SD	Range
FIS	111.6	11.12	96–128	113.5	13.23	90–130	122.4	9.55	106–146	135.0	8.04	116–148
EIS	117.9	9.85	94–124	114.3	14.37	94–138	130.5	19.53	86–160	117.7	14.61	90–140
FIL	114.4	9.65	98–124	125.12	6.93	98–140	140.24	6.59	128–152	151.7	7.40	134–168
EIL	113.4	6.80	100–126	119.3	6.32	102–128	136.6	6.01	126–148	150.4	6.48	130–158

Diastolic BP (mm Hg)

Exercise Groups	Baseline			10 Repetitions			15 Repetitions			20 Repetitions		
	$\bar{X}$	SD	Range	$\bar{X}$	SD	Range	$\bar{X}$	SD	Range	$\bar{X}$	SD	Range
FIS	79.5	3.70	70–86	80.6	4.06	70–86	82.2	3.82	74–88	82.7	6.29	74–88
EIS	77.4	4.92	70–86	82.0	5.44	70–86	81.0	4.83	70–86	81.3	9.43	70–86
FIL	79.0	4.69	70–90	79.2	5.13	70–90	83.4	3.45	78–92	86.2	2.90	78–92
EIL	76.8	5.77	70–90	78.1	5.27	70–88	81.6	5.32	70–90	76.8	8.88	70–92

Rate-Pressure Product (10^{-2})

Exercise Groups	Baseline			10 Repetitions			15 Repetitions			20 Repetitions		
	$\bar{X}$	SD	Range	$\bar{X}$	SD	Range	$\bar{X}$	SD	Range	$\bar{X}$	SD	Range
FIS	87.8	8.77	74–106	98.6	12.13	80–123	109.3	12.18	98–141	122.7	12.72	96–140
EIS	92.5	9.58	74–104	93.0	15.55	68–127	102.9	24.59	69–160	92.6	17.91	70–126
FIL	90.9	11.05	74–122	110.9	16.41	78–141	144.0	16.04	112–175	220.1	16.57	176–246
EIL	90.5	7.28	74–106	108.9	12.76	88–134	134.0	12.42	108–154	168.6	12.36	148–203

[a] FIS=flexion in standing, EIS=extension in standing, FIL=flexion in lying, EIL=extension in lying, BP=blood pressure.

summary for RPP differences from baseline is presented. The RPP prior to exercise was not different among groups ($P<.34$) (Fig. 2). However, the RPP after 10, 15, and 20 repetitions differed among groups for all repetitions ($P<.000$). After 15 repetitions, the work of the heart during lying (FIL and EIL) was greater than that during standing (FIS and EIS) ($P<.01$). After 20 repetitions, the work of the heart was different across all exercise groups (ie, FIL>EIL>FIS>EIS) ($P<.01$).

Discussion and Clinical Implications

The results of our study support the hypothesis that repetitive McKenzie exercises for the lumbar spine elicit hemodynamic stress. They increase the work of the heart in people with no known spinal impairments and no cardiovascular or cardiopulmonary insufficiencies. These effects were greater with increased numbers of repetitions. The increased myocardial work, assessed noninvasively using RPP, reflects increases in both HR and BP during multiple repetitions of 4 McKenzie exercises that are commonly used in orthopedic assessment and management of back pathology: FIS, EIS, FIL, and EIL. Because an increased RPP is an indicator of increased myocardial oxygen demand, the results of our study strongly support the idea that these McKenzie exercises, typically performed within 1 minute, represent a risk for a patient with underlying cardiovascular dysfunction. The degree to which an increase in RPP, an index of cardiovascular stress, represents cardiovascular strain depends on the underlying pathophysiology. Thus, a given absolute increase of RPP may be inconsequential in a person without cardiovascular or pulmonary pathology; however, it may constitute marked hemodynamic strain in an individual with such pathology.

Based on the magnitudes of the ICCs, we are confident about the validity and reliability of our BP measurements from which RPP is derived. Blood pressure measurements were recorded by the same person with strict adherence to American Heart Association standards for manual BP measurement.[39] Adherence to these standards increases their correspondence to the gold standard (ie, intra-arterial brachial BP).

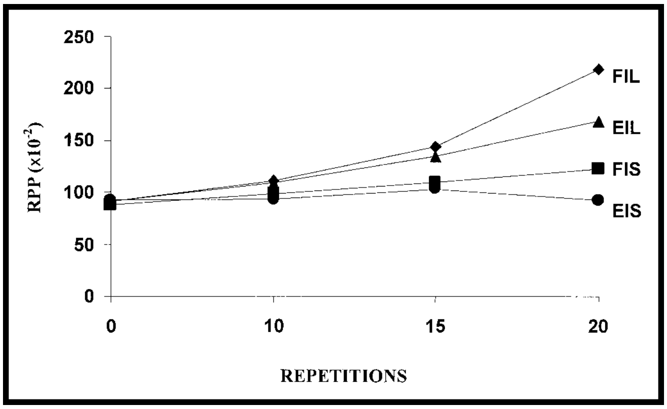

Figure 2.
Mean rate-pressure products (RPP) across groups and repetitions. Zero repetitions=baseline. Results of *post hoc* tests: at 10 repetitions: FIL>FIS*, FIL>EIS**, EIL>EIS**; at 15 repetitions: FIL>FIS**, FIL>EIS**, FIS>EIS**, EIL>FIS**, EIL>EIS**; at 20 repetitions: FIL>EIL>FIS>EIS**. *=$P<.05$, **=$P<.01$. FIS=flexion in standing, EIS=extension in standing, FIL=flexion in lying, EIL=extension in lying.

Cardiovascular demands were greater after 20 repetitions of each of the 4 exercises, with the demands of the exercises increasing to a greater extent in lying positions (FIL>EIL) than in upright positions (FIS>EIS). This result is consistent with known physiology.[8,33] Because of cephalad fluid shifts in lying, which increase venous return and central blood volume, the demand on the heart in this position is greater than in standing. This is the basis for a recommendation published almost 50 years ago that advocated placing patients with cardiac conditions in chairs rather than in beds to reduce myocardial work.[41]

Both FIL and EIL produced increases in HR, BP, and RPP following 15 and 20 repetitions of exercise. Flexion in lying involves the work of a large muscle mass of the upper and lower extremities, the abdominal muscles, and the trunk muscles (acting in a stabilizing role); therefore, the demand for oxygen to supply the contracting muscles is increased. Consequently, the HR, BP, cardiac output, and stroke volume are increased.[37] Because of the increased effort associated with FIL, the inadvertent holding of breath and increased intrathoracic pressure can increase the resistance to blood returning to the heart, which leads to a reflex increase in HR and BP.

In order to effect lumbar extension, EIL, a modified push-up exercise, involves upper-extremity muscles to raise the upper-trunk weight against gravity. The results of our study show that EIL increases the work of the heart at 15 and 20 repetitions. Several authors[8,25,33–37] have reported that, at a constant work rate, HR, systolic BP, and RPP are greater during arm exercise than during leg exercise.

The standing position is associated with less cardiac work, particularly during back extension. Flexion in standing appears to require the eccentric contraction of the back muscles, followed by their concentric contraction to return to the upright position. Extension in standing appears to require eccentric contractions of the abdominal muscles to effect back extension, followed by their concentric contraction to return to the upright position.[42] Because the range of motion during back extension is less than during flexion, there is presumably less muscle work, and, therefore, less work of the heart in extension compared with flexion in both the lying and standing positions.

Our results indicate that physical therapists should consider monitoring the cardiovascular status of patients with spinal problems for which McKenzie exercises are indicated. This is especially true for people with risk factors and who may have asymptomatic or symptomatic cardiovascular disease, cardiopulmonary disease, or hypertension. In addition, deconditioning, smoking, and obesity increase demands on the heart. Therefore, we believe the standard McKenzie evaluation form should include a cardiac and pulmonary risk factor assessment. We argue that ruling out cardiovascular and pulmonary disease by interviews and questionnaires alone is not sufficient. We contend that baseline HR and BP should be routinely recorded.

In our study, we found that 10 repetitions of spinal loading exercises in lying or standing positions are associated with the least cardiovascular stress. Our results indicate that that the classic McKenzie exercise of "extension in standing" is the least stressful hemodynamically and, therefore, theoretically the least risky.

Cardiovascular responses, in our opinion, also should be considered when repetitive McKenzie exercises for the lumbar spine are prescribed for a home exercise program. We believe patients should be warned not to exceed the prescribed number of repetitions and sets for each exercise. We also contend that, when prescribing FIL, the physical therapist should closely monitor the patient during performance of the exercise to discourage inadvertent breath holding or straining. Cardiovascular self-monitoring skills should be taught to patients with risk factors.

Routine monitoring of HR and BP as a fundamental component of all physical therapist examinations is consistent with contemporary preferred practice patterns.[43] Patients with cardiovascular disease, cardiopulmonary disease, hypertension, or the risk factors for these conditions should be screened carefully. Although, to the best of our knowledge, adverse cardiovascular effects of McKenzie exercises have not been docu-

Table 4.
Analysis of Variance Table for Rate-Pressure Product Across Groups and Repetitions

Variable	Source	*df*	SS	MS	F	*P*
Baseline	Between groups	3	287.03	95.68	1.11	.348
	Within groups	96	8262.20	86.07		
After 10 repetitions	Between groups	3	5414.82	1804.94	8.79	.000
	Within groups	96	19719.29	205.41		
After 15 repetitions	Between groups	3	34159.93	11386.64	40.09	.000
	Within groups	96	27267.19	284.03		
After 20 repetitions	Between groups	3	232147.00	77382.34	339.97	.000
	Within groups	96	21851.00	227.612		

mented, awareness of these effects is important so that these exercises, which are commonly used in patients with a primary orthopedic diagnosis, may be judiciously prescribed.

Conclusion

Repetitive McKenzie exercises for the lumbar spine used in the routine assessment and management of low back pain have cardiovascular effects in people with no cardiovascular or cardiopulmonary conditions and who are within an age range of people susceptible to low back pathology. This effect is accentuated with increasing repetitions. We conclude that these effects are important with respect to cardiac work and that patients for whom these exercises are prescribed require a cardiac and pulmonary risk factor assessment to establish whether HR and BP should be monitored. The magnitude of the risk associated with lumbar spinal loading exercises reflects the type and severity of underlying cardiovascular or cardiopulmonary pathology, the type of spinal loading exercise, breathing rhythm, the number of repetitions and their pacing, and the number of sets and their frequency throughout the day. Although, to the best of our knowledge, adverse cardiovascular effects of McKenzie lumbar spine exercises have not been documented, practitioners have a responsibility to ensure the safety and judiciousness of the exercises they prescribe. Monitoring HR and BP provides an index of the work of the heart, and erring on the side of caution in those people who are at risk for cardiovascular and cardiopulmonary conditions (eg, reducing the number of repetitions to 10 or fewer) is a defensible guideline. Further research is needed to elucidate those factors that increase the risk for a given patient. Electrocardiographic studies would help establish the effect of these exercises on cardiac rhythm and provide a guide to how they should be performed.

References

1 Jacobard G, McKenzie R. Spinal therapeutics based on responses to loading. In: Liebenson C, ed. *Rehabilitation of the Spine: A Practitioner's Manual*. Baltimore, Md: Williams & Wilkins; 1996:225–252.

2 Masten T, Donelson R. The McKenzie approach to patient classification: a physician perspective. *Orthopedic Physical Therapy Clinics of North America*. 1995;4:193–208.

3 DiMaggio A, Mooney V. The McKenzie program: exercise effectiveness against back pain. *Journal of Musculoskeletal Medicine*. 1987;4(12):63–74.

4 McKenzie RA. *The Lumbar Spine: Mechanical Diagnosis and Therapy*. Waikanae, New Zealand: Spinal Publications; 1981:27–80.

5 McKenzie RA. *The Cervical and Thoracic Spine: Mechanical Diagnosis and Therapy*. Waikanae, New Zealand: Spinal Publications; 1990:69–102, 151.

6 McKenzie RA. Mechanical diagnosis and therapy for the disorders of the low back in physical therapy. In: Twomey L, Taylor J, eds. *Clinics in Physical Therapy*. 2nd ed. London, England: Churchill Livingstone; 1994:187.

7 Donelson R, Grant W, Kamps C, Medcalf R. Pain response to sagittal end-range spinal motion: a prospective, randomized, multicentered trial. *Spine*. 1991;16(suppl 6):S206-S212.

8 McArdle WD, Katch FI, Katch VL. *Essentials of Exercise Physiology*. Philadelphia, Pa: Lea & Febiger; 1994.

9 Mandell P, Lipton M, Bernstein J, et al. *Low Back Pain*. Thorofare, NJ: Slack Inc; 1989:22.

10 Multiple Risk Factor Intervention Trial Research Group. Multiple risk factor intervention trial: risk factor changes and mortality results. *JAMA*. 1982;248:1465–1477.

11 Svensson H-O, Vedin A, Wilhelmsson C, Andersson GBJ. Low-back pain in relation to other diseases and cardiovascular risk factors. *Spine*. 1983;8:227–285.

12 Waddell G. *The Back Pain Revolution*. Edinburgh, Scotland: Churchill Livingstone; 1988:85–101.

13 Kelsey JL, Githens PB, O'Conner T, et al. Acute prolapsed lumbar intervertebral disc: an epidemiologic study with special reference to driving automobiles and cigarette smoking. *Spine*. 1984;9:608–613.

14 Gyntelberg F. One year incidence of low back pain among male residents of Copenhagen aged 40–59. *Dan Med Bull*. 1974;21:30–36.

15 Tibblin G. High blood pressure in men aged 50: a population study of men born in 1913. *Acta Med Scand*. 1967;470:1–84.

16 Westrin CG. Low back sick-listing: a nosological and medical insurance investigation. *Acta Sociomed Med Scand*. 1970;2:127–134.

17 Frymoyer JW, Pope MH, Constanza MC, et al. Epidemiologic studies of low-back pain. *Spine*. 1980;5:419–423.

18 Astrand PO, Saltin B. Maximal oxygen uptake and heart rate in various types of muscle activity. *J Appl Physiol.* 1961;16:977–983.

19 Franklin BA. Exercise testing, training and arm ergometry. *Sports Med.* 1985;2:100–119.

20 Sawka MN. Physiology of upper body exercise. *Exerc Sport Sci Rev.* 1986;14:175–211.

21 *ACSM's Guidelines for Exercise Testing and Prescription.* 5th ed. Philadelphia, Pa: Williams & Wilkins; 1995.

22 American Association of Cardiovascular and Pulmonary Rehabilitation. *Guidelines for Cardiac Rehabilitation Programs.* Champaign, Ill: Human Kinetics; 1995.

23 Celli BR. The clinical use of upper extremity exercise. *Clin Chest Med.* 1994;15:339–349.

24 MacMasters WA, Harned DJ, Duncan PW. Effect of exercise speed on heart rate, systolic blood pressure, and rate-pressure product during upper extremity ergometry. *Phys Ther.* 1987;67:1085–1088.

25 Gobel FL, Nordstrom LA, Nelson RR, et al. The rate-pressure product as an index of myocardial oxygen consumption during exercise in patients with angina pectoris. *Circulation.* 1978;57:549–556.

26 Kispert CP. Clinical measurements to assess cardiopulmonary function. *Phys Ther.* 1987;67:1886–1890.

27 Kodama Y, Yokota M, Miyahara T, et al. Effect of antianginal agents on the relationship between rate-pressure product and myocardial oxygen uptake. *Am Heart J.* 1993;126:587–593.

28 May GA, Nagle FJ. Changes in rate-pressure product with physical training of individuals with coronary artery disease. *Phys Ther.* 1984;64:1361–1366.

29 Nielsen DH, Kispert CP, Archer JM, Ahrens RC. Cardiovascular adaptations to isokinetic cycling exercise [abstract]. *Phys Ther.* 1984;64:722.

30 Greer M, Dimick S, Burns S. Heart rate and blood pressure response to several methods of strength training. *Phys Ther.* 1984;64:179–183.

31 Astrand PO, Rodahl K. *Textbook of Work Physiology.* 3rd ed. New York, NY: McGraw-Hill Inc; 1986.

32 Astrand I. Circulatory responses to arm exercise in different work positions. *Scand J Clin Lab Invest.* 1971;27:293–297.

33 Bevegard S, Freyschuss U, Strandell T. Circulatory adaptation to arm and leg exercise in supine and sitting position. *J Appl Physiol.* 1966;1:37–46.

34 DeVries H, Adams G. Total muscle mass activation versus relative loading of individual muscles as determinants of exercise response in older men. *Med Sci Sports.* 1972;4:146–154.

35 Stenberg J, Astrand PO, Ekblom B, et al. Hemodynamic response to work with different muscle groups, sitting and supine. *J Appl Physiol.* 1967;22:61–70.

36 Mitchell JH, Wildenthal K. Static (isometric) exercise and the heart: physiological and clinical considerations. *Ann Rev Med.* 1974;25:369–381.

37 Reindl AM, Gotshall RW, Reinke JA et al. Cardiovascular response of human subjects to isometric contraction of large and small muscle groups. *Proc Soc Exp Biol Med.* 1977;154:171–174.

38 Dean E. Physiology and therapeutic implications of negative work: a review. *Phys Ther.* 1988;68:233–237.

39 Recommendations for routine blood pressure measurement by indirect cuff sphygmomanometry. *Am J Hypertension.* 1992;5:207–209.

40 Fleiss JL. *The Design and Analysis of Clinical Experiments.* Toronto, Ontario, Canada: John Wiley & Sons Ltd; 1986.

41 Levine SA, Lown B. "Armchair" treatment of acute coronary thrombosis. *JAMA.* 1952;148:1365–1369.

42 Porterfield JA, DeRosa C. *Mechanical Low Back Pain: Perspectives in Functional Anatomy.* Philadelphia, Pa: WB Saunders Co; 1991.

43 *Guide to Physical Therapist Practice.* Alexandria, Va: American Physical Therapy Association; 1997.